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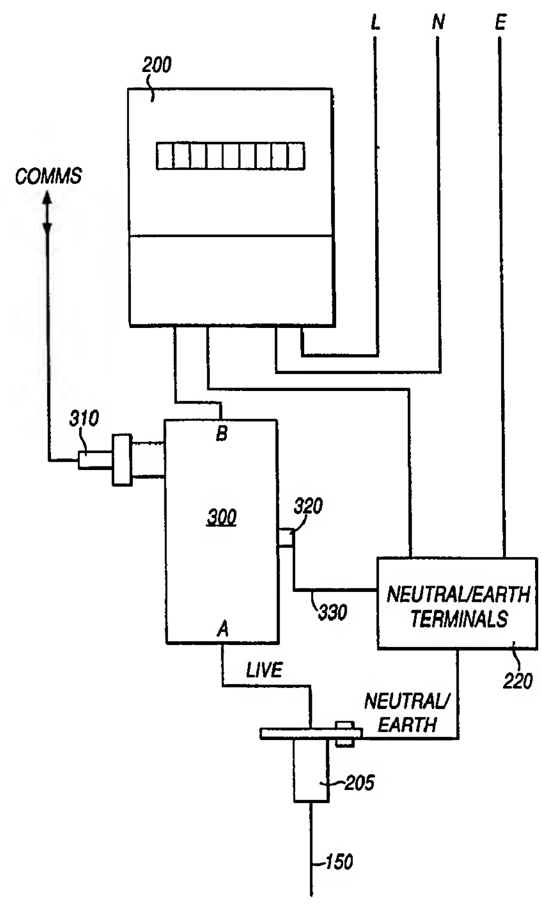
(54) Title: POWER LINE TRANSMISSION

(57) Abstract

A power line communications network carries power and communications signals over power lines. Fitted in the power line is a fuse unit (300) which has means for coupling communications signals to and/or from the power line. The fuse unit may include a high–pass filter. The fuse unit (300) is adapted to mate with an existing fuse socket in the power line to replace an existing fuse, thereby minimising disruption and simplifying installation. The fuse unit can also include means for impeding flow of non–power signals along the line.



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POWER LINE TRANSMISSION

TECHNICAL FIELD

This invention relates to transmission of communications signals over power lines.

BACKGROUND OF THE INVENTION

It is known to transport telecommunications signals over an electricity distribution or power transmission network. Patent Application WO 94/09572 A1 (Norweb) describes such a network. Delivering a telecommunications service in this manner is attractive as it avoids the need to install new cabling to each subscriber. By using existing electricity distribution cabling to carry telecommunications signals, significant cost savings are possible.

One example of an electricity distribution network which is adapted to carry telecommunications signals is shown in figure 1. Mains electricity enters the network from a 6 or 11kV transmission line 105 and is transformed by substation 100 into a 415V supply which is delivered over distribution cable 120 to subscribers S1, S2, S3. A base station BS couples telecommunications signals onto distribution cable 120 at point 110. The telecommunications signals propagate over the cable on radio frequency carriers to transceiver units at each of the subscriber premises S1-S3. Equipment at one of the subscribers, subscriber S3, is shown in detail. Each subscriber to the telecommunications service requires some means 160 for coupling signals to and from the power line. In the upstream direction signals must be extracted from the power line. In the downstream direction signals must be coupled onto the power line for transmission towards the base station BS.

There are also concerns as to whether premises require a low-pass filter LPF to be installed. The filter has two functions. A first function is to prevent telecommunications signals on cable 150 from flowing onto internal wiring 170 of a premises. RF signals flowing along unshielded internal wiring may radiate and interfere with appliances in the premises. A second function of the low-pass filter is to prevent RF noise generated by electrical equipment 180, such as an electric motor, from flowing onto distributor 120 and corrupting communications signals. The low-pass filter may be needed at all

premises which are coupled to a distribution network which carries telecommunications signals.

In the above-mentioned Patent Application WO 94/09572 A1, a network conditioning element is installed at each subscriber's premises. This conditioning element includes a coupling element for input and/or removal of telecommunications signals from the power line. It also includes a low-pass filter for filtering out the low frequency power signal. This prevents telecommunications signals from contaminating the wiring inside the premises, and minimises noise sources originating inside the premises from propagating onto the power line and corrupting telecommunications signals. Each conditioning element is installed in series with the power line. To do this the electricity supply to the premises is switched off while the conditioning element is installed. The power cable is then severed and the conditioning element is connected to the severed ends of the cable. The installation may also require rearranging of the existing equipment mounted within a subscriber's meter cabinet to accommodate the conditioning element.

It can be seen that the provision of a conditioning element as described above has several inconveniences: the power cable is severed, the electricity supply needs to be switched off while installation of the element takes place and some further work is often necessary to accommodate it.

Power line transmission is one of several ways for delivering communications to the subscriber premises and is therefore sensitive to competition with existing copper wires and more recent alternative fibre optic/coaxial cable and fixed radio access techniques.

The present invention seeks to provide an alternative arrangement for coupling signals to and from a power line.

SUMMARY OF THE INVENTION

According to an aspect of the present invention, there is provided a power line communications network in which power and communications signals are carried over power lines, wherein the power line has a fuse unit which has means for coupling communications signals to and/or from the power line.

According to another aspect of the present invention, there is provided a fuse unit for fitting in a power line which carries both power and communications signals, the unit comprising coupling means for coupling a communications signal to and/or from the power line.

According to a further aspect of the present invention, there is provided a method of coupling communications signals to and/or from a power line which carries both power signals and communications signals, the power line comprising a fuse unit, the method comprising coupling communications signals to and/or from the network via a coupling means incorporated in the fuse unit.

According to a further aspect of the present invention, there is provided a method of installing a connection for coupling communications signals to and/or from a power line which carries both power signals and communications signals, the method comprising removing an existing fuse at a position in the power line and fitting a new fuse unit into the power line in place of the existing fuse, which new fuse unit incorporates means for coupling communications signals to and/or from the power line.

Providing the coupling means as part of a fuse unit has some significant advantages. It overcomes the need to sever a power line to install the coupling means. The consumer's electricity supply need only be momentarily interrupted while the existing fuse is removed and the new fuse unit is fitted, compared with the inconvenience of disrupting a consumer's electricity supply for a long period of time while the prior art coupling means is installed. Further advantages are that it makes the installation work considerably simpler and cheaper and is safer for the installer as he does not need to work with live cables. Installation may therefore be carried out by less experienced personnel. A still further advantage of the fuse unit is that it can be easily replaced if components of the coupling means fail.

A further advantage of this fuse unit is that it overcomes the need to rearrange the contents of the meter cabinet to accommodate a conditioning unit. Rearranging the meter cabinet requires an installer to work with live cables or to switch off the electricity supply to all premises served by that particular live line.

The term "power line" is intended to cover power lines which form part of an electricity distribution network or power transmission network, whether external or internal to a building, including overhead or underground lines.

The term "fuse unit" is intended to cover any kind of replaceable protective device that is installed in a power line.

Communications signals can comprise speech, data, signalling (such as signalling to provide remote meter reading or control of remote appliances) or any combination of these. The communications signals can be carried over the power lines over one or more bands of carrier frequencies using techniques such as FDM, TDM or spread spectrum. Alternatively, line coding techniques can be used to cause a base band data signal to occupy a specific spectral band of the power line.

Preferably the fuse unit comprises impedance matching means for matching impedance of a communications line with impedance of the power line.

Preferably the fuse unit comprises safety means for limiting or preventing flow of power signals from the power line to the communications line in the event that the coupling means fails.

Preferably the fuse unit comprises impeding means for impeding flow of non-power signals along the power line. The impeding means can be a low-pass filter and it is possible to combine the inductance of the low-pass filter with the fuse as an inductive fuse. This has advantage of reducing size of the fuse unit.

According to a still further aspect of the present invention, there is provided a fuse unit for fitting in a power line which carries both power and communications signals, the unit comprising impeding means for impeding flow of non-power signals along the power line.

The impeding means minimises noise generated by appliances from entering the distribution network and minimises the flow of communications signals from the distribution network entering the premises. It also has the

advantage of isolating the communications signals from varying loading effects of equipment coupled to the power line.

Preferred features may be combined as appropriate, and may be combined with any of the aspects of the invention, as would be apparent to a person skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, and to show by way of example how it may be carried into effect, embodiments will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a power line communication system;

Figure 2 shows a typical installation at a subscriber's premises;

Figure 3 shows the installation of figure 2 incorporating a fuse unit according to an embodiment of the invention;

Figure 4 shows a side view of a fuse unit according to an embodiment of the invention;

Figure 5 is a schematic diagram of a fuse unit for use in the arrangement of figure 3;

Figure 6 shows a modification of the fuse unit of figure 5 with multiple output ports;

Figure 7 is a schematic diagram of an alternative fuse unit for use in the arrangement of figure 3;

Figure 8 is a side view, partly cut away, of a fuse for use in the unit of figure 7;

Figure 9 is a schematic diagram of a further alternative fuse unit for use in the arrangement of figure 3.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring again to the electricity distribution network shown in figure 1, substation 100 distributes electricity to subscribers over distributors 120, 130, 140. Each distributor 120 typically comprises a three-phase 415V line. Although three subscribers S1, S2, S3 are shown, a full system will include many more subscribers. A domestic subscriber couples to a single phase line of distribution cable 120 by a branch line 150. Telecommunication signals propagate along distributor 120 and to a subscriber's premises via

branch line 150. One scheme for transporting communications signals uses a band of carrier frequencies in the range 2-6MHz and the CT2 protocol.

Figure 2 shows a typical installation at the meter cabinet of an electricity subscriber. An electricity supply together with any telecommunications signals carried thereon, enters the cabinet on branch line 150. Branch line 150 is a coaxial cable having a main conductor carrying one of the three phases from distributor 120 plus an outer braid which carries a combined neutral and earth. At junction 205 the live and neutral lines are separated. The neutral/earth passes to neutral/earth terminals junction box 220. The live line passes through a fuse 210 to a consumption meter 200. Fuse 210 belongs to the utility company and is often called the utility fuse. This fuse protects branch line 150, typically having a rating of 100A, and is also a mechanism for allowing the service provider to cut-off a subscriber from the supply. Live (L), neutral (N), and earth (E) lines lead from the meter cabinet to provide a power supply to the consumer via the internal wiring of the premises. It is known to insert the conditioning element of WO 94/09572 into the meter cabinet at position A-A by cutting the live cable.

Figure 3 shows the installation of figure 2 with the fuse 210 replaced by a fuse 300 which incorporates means for coupling signals to and from the live cable. Modified fuse 300 plugs into the existing fuse carrier in place of fuse 210 and requires no modification to the existing installation. Fuse unit 300 has an output 310 to couple to a cable which carries communications signals to and from communications equipment in the subscriber's premises. Communications signals are transmitted between a phase line and neutral/earth. The coupling means within fuse unit 300 therefore has a connection to both the phase line (live) and to neutral/earth to apply/remove communications signals. Fuse unit 300 has a second connector 320 to allow a cable 330 to couple the fuse unit to an earth terminal in the meter cabinet. The connection to earth is also required for protection, providing a path to earth in the event that a component in the fuse unit fails, and to provide a path to earth for the low-frequency signals. Consumption meter 200 has been found to attenuate communications signals occupying a frequency of several megahertz or more. Coupling signals to and from the power line on the utility company's side of the consumption meter avoids the attenuating properties of the meter.

Figure 4 shows a side view of the modified fuse unit 300. As with a conventional fuse unit, the modified unit has connection tangs 410, 420 to mate to complimentary fittings in the fuse carrier in the meter cabinet. It also includes a cartridge fuse 400, having a rating typically of 100A. A housing above the cartridge fuse comprises two sections 430, 440. Section 430 resembles a normal fuse carrier so that the modified fuse can fit within an existing fuse socket. Section 440 comprises an additional housing mounted on top of the other housing 430 which incorporates the additional circuitry needed for coupling signals to and from the line. Communications signal connector 310 and earth connector 320 are provided on the periphery of housing 440. The position of the connectors around the periphery can be conveniently chosen so as to make installation easier e.g. the earth connector 320 can be provided opposite the position at which the earth terminal is located in the meter cabinet and the communications signal connector 310 can be provided adjacent the point at which communications cables lead from the meter cabinet. Communications signal connector 310 is a coaxial connector such as a F-type or a BNC type.

Most meter cabinets are sufficiently deep to accommodate the increased height of fuse unit 300. However, a problem with clearance within the cabinet can be resolved by forming section 440 in a shape such that fits within the available space inside the cabinet, or by making section 440 of the fuse unit a separate module linking by cables to section 430. This allows the coupling circuitry to be placed at a convenient position in the meter cabinet where there is sufficient room.

Figure 5 shows, in the form of a schematic diagram, circuitry which is incorporated within fuse unit 300. The fuse unit is connected in the meter cabinet such that A and B in figure 5 correspond to A and B in figure 3. Capacitor C1 and the combined inductances of inductor L1 and transformer T1 function as a high pass filter which allows communication signals at RF to appear across transformer T1 and at connector 310. The spectral response of the high-pass filter is chosen so as to pass the spectral band used by communications signals and to block mains signals at 50/60Hz. Alternative filter arrangements can be used, e.g. higher-order filters providing a sharper roll-off response, band-pass filters which pass only a particular band of frequencies. These may be useful in situations where there are several

bands of communications signals on the power line, and a subscriber requires only one of these bands.

Several safety measures are also incorporated to prevent mains current from the live line flowing onto coaxial connector 310 and towards communications equipment. The first safety feature is the provision of fuse F2 in series with capacitor C1. In the event that C1 fails short-circuit, fuse F2 will blow, thus causing an open circuit and preventing any further flow of current. Fuse F2 has a rating of 1 amp and will blow if this current is exceeded. Also, capacitor C1 is a Y class capacitor which is designed to fail open circuit. This minimises the chance of a short circuit failure. Another safety feature is the provision of transformer T1 which has the effect of isolating connector 310 from the live supply should the other safety features fail. As a further safety feature, the ground shield of coaxial connector 310 may be coupled to earth connector 320 via link 500 between the primary and secondary windings of transformer T1.

Inductor L1 has the effect of passing mains, low frequency, signals to earth and also to pass fault current to earth. In the event that C1 fails short-circuit L1 helps to pass mains current to earth and to quickly blow fuse F2. Diode D1 is a transient absorber (transorb) which minimises the effect of transients in the mains supply on the RF communications signals.

Transformer T1, as well as having an isolating function, also matches the impedance of the communications transmission line to the impedance of the power supply line. A communications line typically has an impedance of 50 or 75½, and a power supply line typically has an impedance of 10 to 20½. The ratio of the number of turns on the primary and secondary windings of transformer T1 determine the impedance matching characteristics. As an example, to match a power supply line impedance of 20½ to a communications line impedance of 50½, a turns ratio of 1:2.5 is required, i.e. $2\frac{1}{2}$ times as many turns on the communications line side of the transformer to that on the power supply side. The fuse unit can be inserted into fuse carrier of figure 3 the opposite way around. The way shown in figure 5 is preferred as it ensures that even when the fuse has blown, cutting off the electricity supply to the premises, communications signals can still be coupled to and from the power line.

Figure 6 shows a modified version of the unit of figure 5 which has multiple output ports 310, 315. A first filter F1 and a second filter F2 each pass a particular band of the signals which are received by transformer T1 (and similarly in reverse direction pass a particular band of signals for applying to transformer T1). The separate bands could each carry a particular communications service. Further filters and output ports can be provided in the same manner.

Figure 7 schematically shows an alternative fuse unit 300. This unit incorporates the coupling function of the unit shown in figure 5 and, in addition, has a filtering function which passes communications signals to ground such that they do not flow onto the internal wiring of a subscriber's premises. This fuse is coupled to the meter cabinet such that the letters A and B correspond to A and B as shown in the meter cabinet of figure 2. The main modifications of this circuit compared to that of figure 5 are the addition of inductance L2 in series with the main fuse in the path directly between A and B and the addition of a further capacitor C2 coupled between connector B and earth connector 320. Communication signals are extracted on the supply side of the main fuse and pass through a filter arrangement C1, L1 as before. L2 and C2 act as a low-pass filter which allow only mains signals to flow from terminal B onto the internal wiring of the premises. Fuse F3 is rated at e.g. 1 amp so as to blow in the event that capacitor C2 fails short-circuit.

There are two ways of incorporating an inductance L2 in series with the main fuse. A first way is to couple an inductor in series with the main fuse. An alternative arrangement is to combine the function of the fuse and the inductor into an inductive fuse.

Figure 8 shows one example of how an inductive fuse can be realised. A conventional end cap and lugs 700 are provided at each end of a ceramic body 710. Fuse wire 720 of a suitable fuse rating is wound upon a ferrite rod 725. The ferrite rod should have an electrically insulative coating such as vitreous enamel which is able to withstand high temperatures. The void 730 between the wound ferrite rod 725 and ceramic body 710 is filled with silica powder. This has the effect of absorbing any metal which becomes vaporised during blowing of the fuse. It is preferred that the fuse wire is wound in three distinct sections. At each end of the fuse the fuse wire is

wound closely 740 to provide high inductance and in the central area 750 the fuse wire is open wound to provide a rupture section. The open-wound rupture section ensures that, once wire 720 breaks, the electrical path through the fuse is properly broken. For a conventional size of fuse cartridge and 100A fuse wire, an inductance of 10μH should be possible with this arrangement.

The circuitry of figures 5 to 7 is mounted on a printed circuit board that is supported within housing 440 of fuse unit 300. The circuitry is preferably encapsulated within the housing using epoxy resin or a similar substance. The encapsulation prevents tampering of the circuitry which is an important factor when the fuse is present on the supply, non-metered, side. It also increases safety, and prevents ingress of moisture and dirt into the circuitry.

The fuse units just described include means for coupling communications signals to/from the power line. When a power line network is used to transport communications signals it may be necessary to install a low-pass filter at each premises served by that network, whether or not each premises subscribes to the communications service. This is to ensure that there is no RF radiation within premises, and to minimise leakage of RF noise onto the network. The fuse unit of figure 6 can be used just as a filter. To ensure that RF does not radiate from coaxial connector 310 a termination can be fitted to the connector.

Figure 9 shows an alternative fuse unit with just a low-pass filter. The same low-pass filter of figure 6 having the components (L2, C2) and protection fuse F3 have been used. However, other filters such as higher-order low-pass filters could also be used.

The detailed description describes how a utility fuse in a consumer's meter cabinet can be replaced by a fuse incorporating coupling means and/or a filter. However, it will be appreciated that fuses and other replaceable protective devices at other points in a power network could be replaced in a similar manner. In some countries where overhead power lines are used it is known to have a replaceable fuse mounted on a fascia board of a premises; this can be replaced in a similar manner.

It is also possible to replace a meter or monitoring unit which conveniently plugs into a power line with a meter that has means for coupling communications signals to and /or from the power line in which it is fitted.

CLAIMS

1. A power line communications network in which power and communications signals are carried over power lines, wherein the power line has a fuse unit which has means for coupling communications signals to and/or from the power line.

2. A power line communications network according to claim 1 wherein there is a fuse socket fitted in series with the power line and the fuse unit is adapted to mate with the fuse socket and to replace an existing fuse.

3. A power line communications network according to claim 1 or 2 wherein the fuse unit further comprises means for impeding flow of non-power signals along the power line.

4. A power line communications network according to any one of claims 1 to 3 wherein the communications signals are carried between a phase line and neutral/earth of the power line, and wherein the fuse unit fits in series with a live line of the power line and has a link to couple to neutral/earth.

5. A fuse unit for fitting in a power line which carries both power and communications signals, the unit comprising coupling means for coupling a communications signal to and/or from the power line.

6. A fuse unit according to claim 5 further comprising means for removably fitting in series with the power line.

7. A fuse unit according to claim 5 or 6 wherein the coupling means comprises means for coupling communications signals carried in a spectral band upon the power line, different from that used by the power signals, to a communications output of the fuse unit.

8. A fuse unit according to claim 7 wherein the coupling means comprises a high-pass filter.

9. A fuse unit according to any one of claims 5 to 8 further comprising impedance matching means for matching impedance of a communications line with impedance of the power line.

10. A fuse unit according to any one of claims 5 to 9 further comprising safety means for limiting or preventing flow of power signals from the power line to the communications line in the event that the coupling means fails.

11. A fuse unit according to any one of claims 5 to 10 further comprising impeding means for impeding flow of communications signals along the power line to one side of the fuse unit.

12. A fuse unit according to claim 11 wherein the impeding means comprises a low-pass filter.

13. A fuse unit according to claim 12 wherein inductance of the low-pass filter is combined with the fuse in an inductive fuse.

14. A fuse unit according to any one of claims 5 to 13 further comprising means for impeding flow of noise signals along the power line to one side of the fuse unit.

15. A fuse unit according to any one of claims 5 to 14 wherein the fuse is a subscriber-end utility fuse.

16. A method of coupling communications signals to and/or from a power line which carries both power signals and communications signals, the power line comprising a fuse unit, the method comprising coupling communications signals to and/or from the network via a coupling means incorporated in the fuse unit.

17. A method of installing a connection for coupling communications signals to and/or from a power line which carries both power signals and communications signals, the method comprising removing an existing fuse at a position in the power line and fitting a new fuse unit into the power line in place of the existing fuse, which new fuse unit incorporates means for coupling communications signals to and/or from the power line.

18. A fuse unit for fitting in a power line which carries both power and communications signals, the unit comprising impeding means for impeding flow of non-power signals along the power line.

19. A power line monitoring unit for fitting in a power line which carries both power and communications signals, the unit comprising coupling means for coupling a communications signal to and/or from the power line.

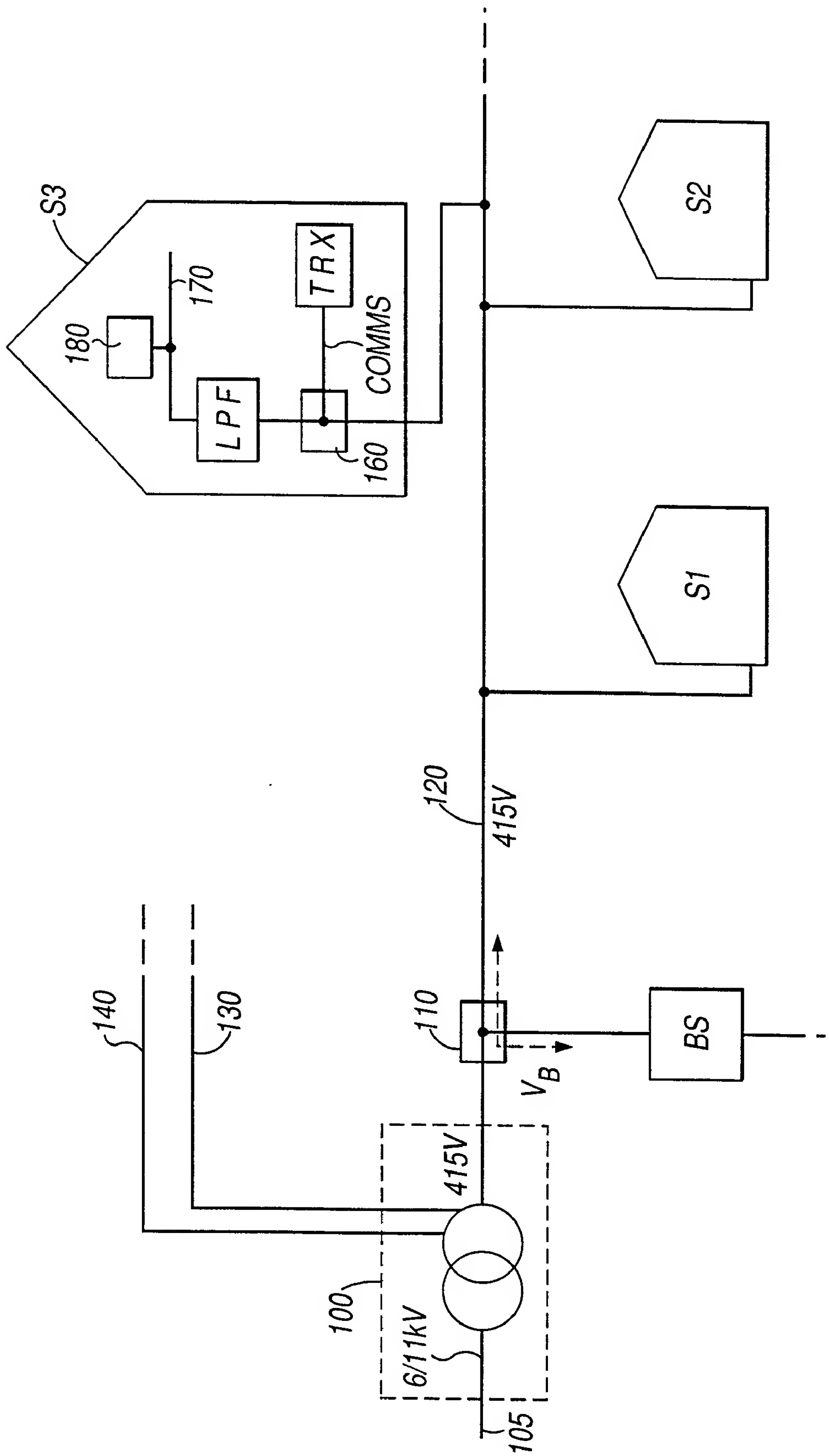
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Fig.1

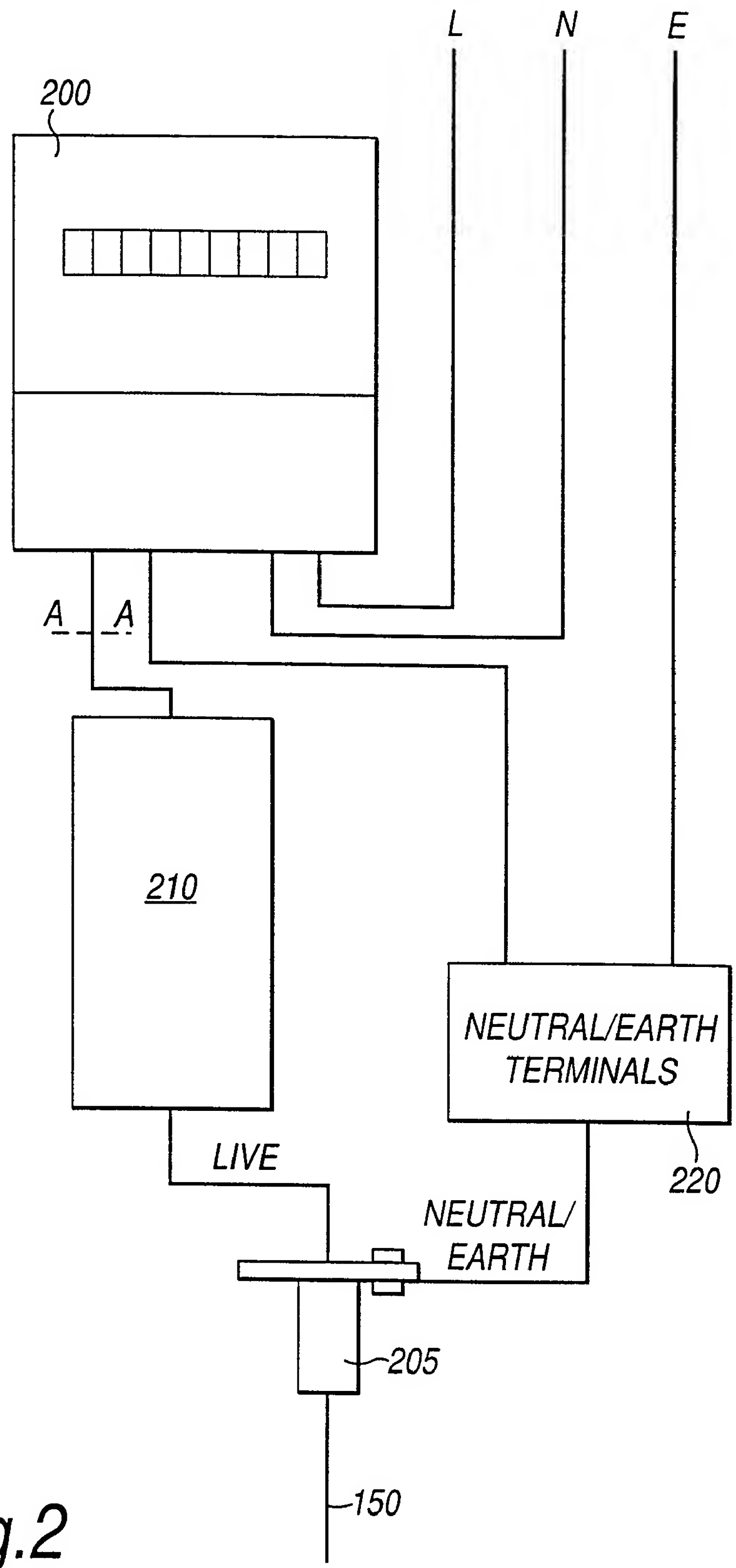
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Fig.2

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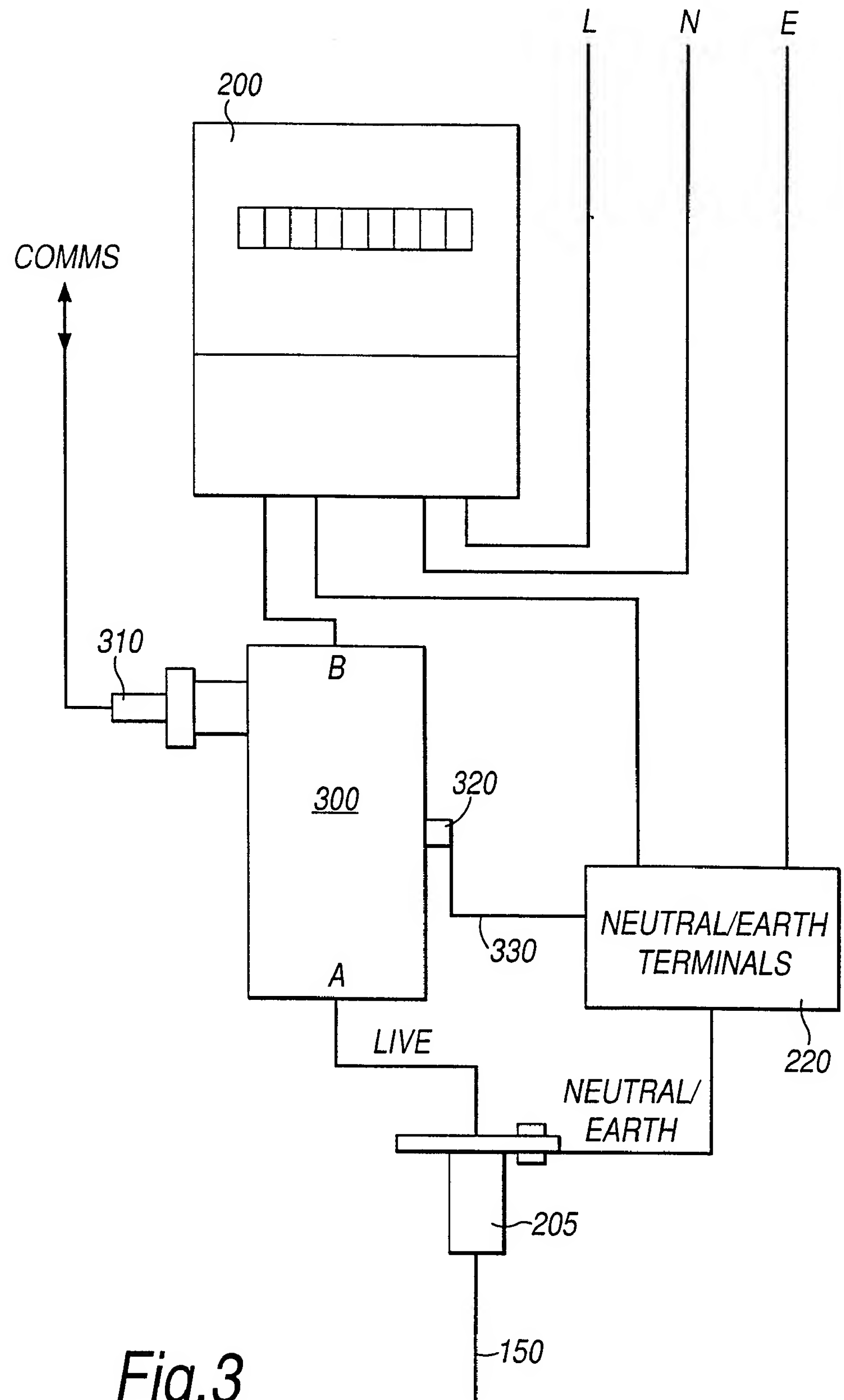
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Fig.3

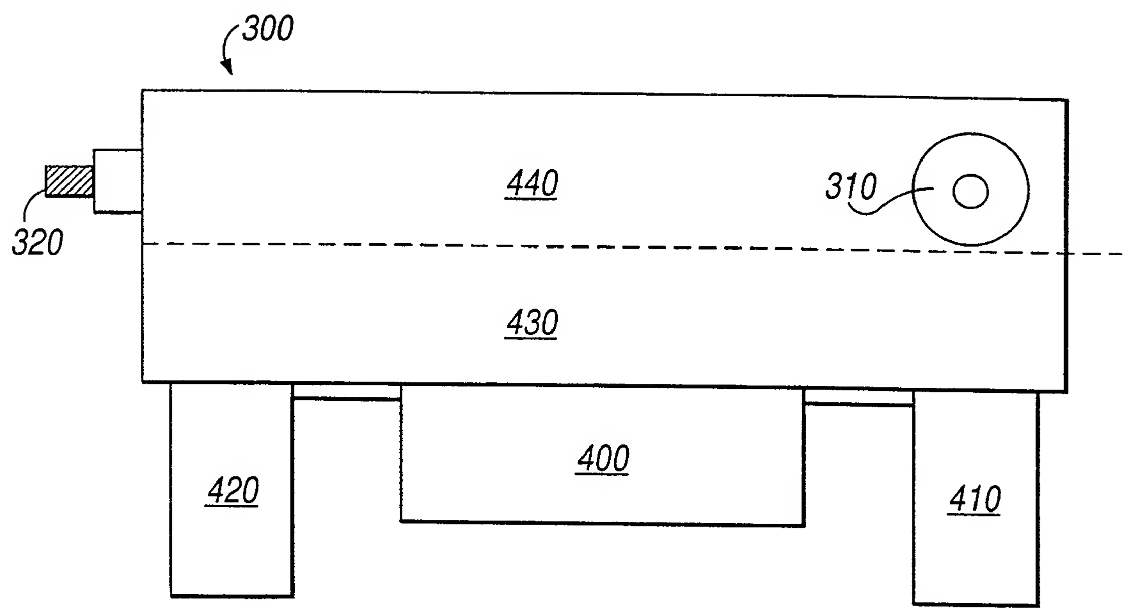
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Fig.4

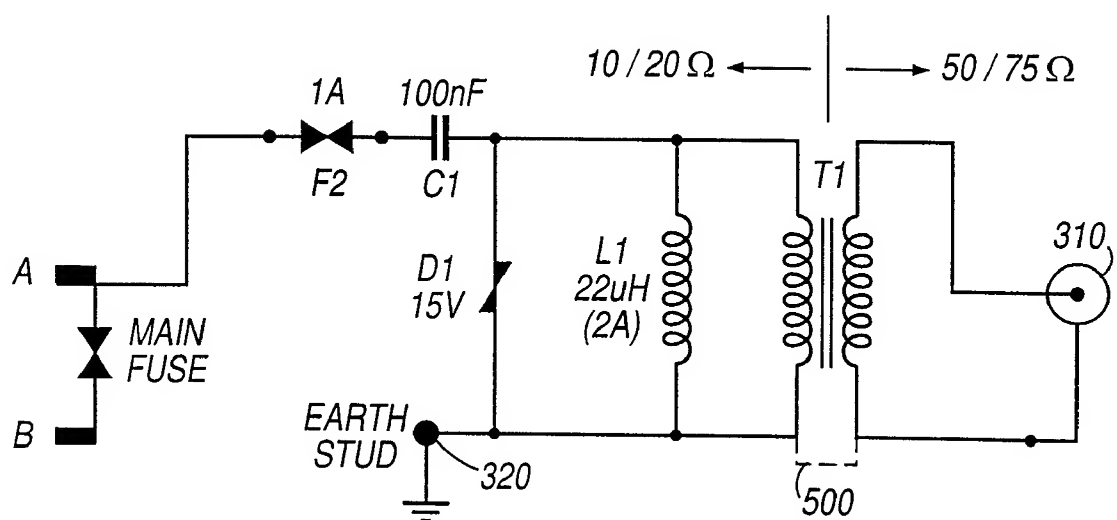
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Fig.5

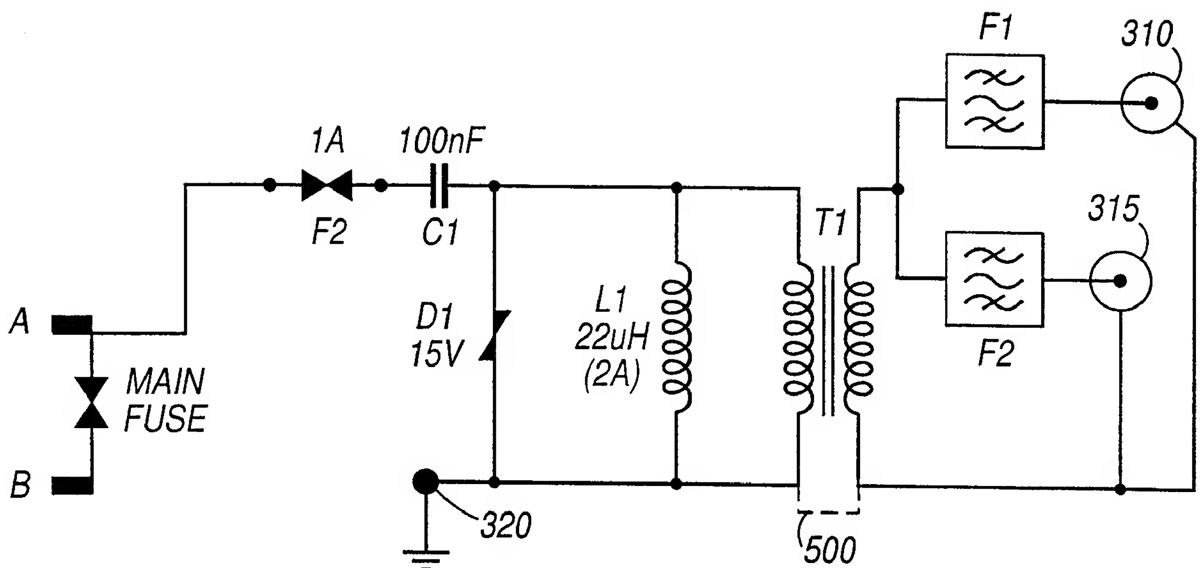
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Fig.6

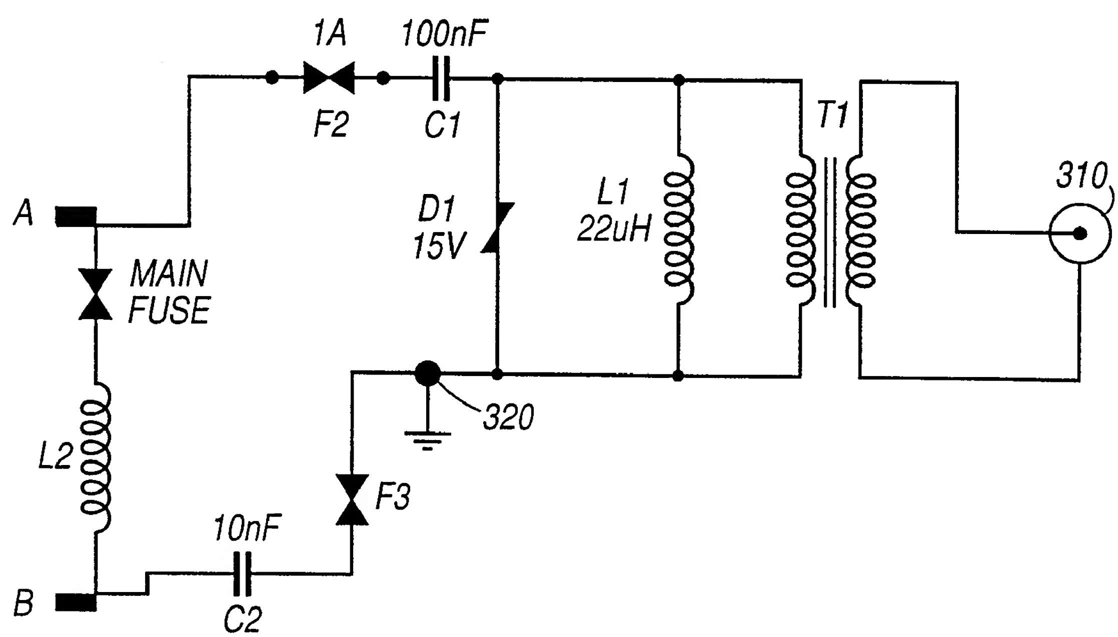
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Fig.7

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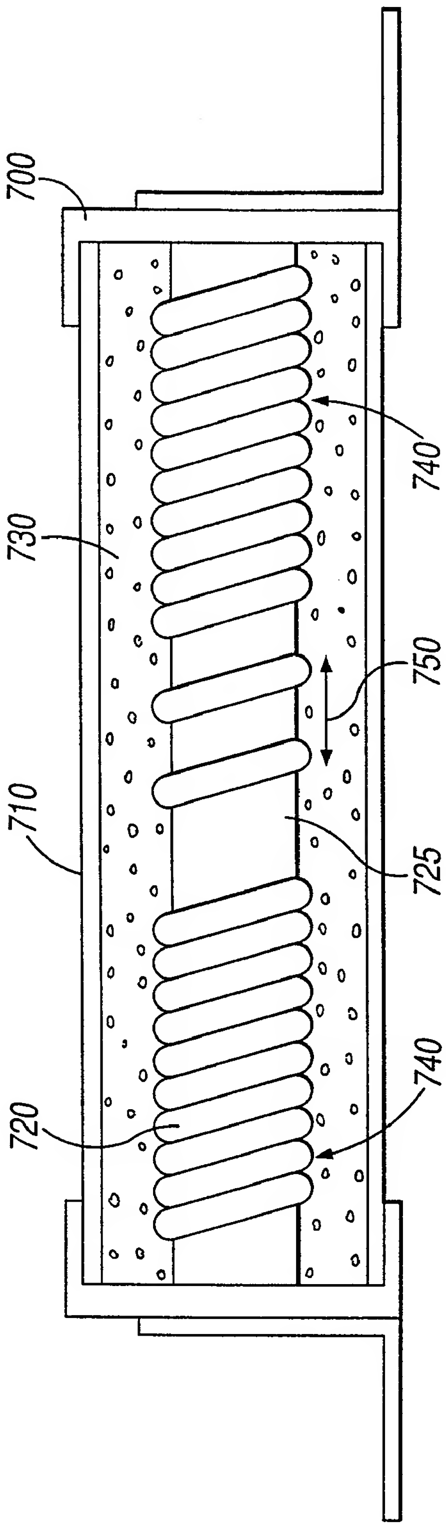

Fig.8

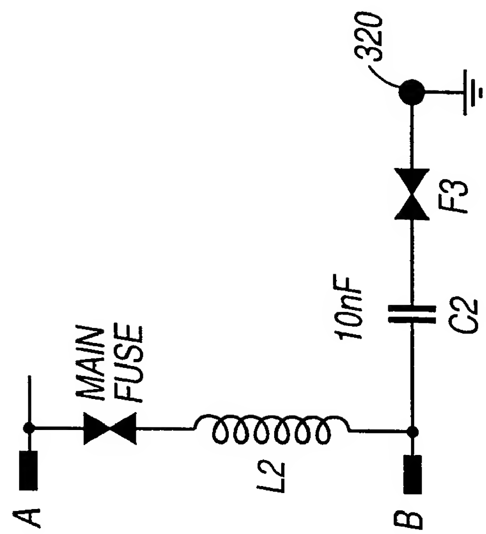

Fig.9